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PLASMA OBSERVATIONS AT COMET HALLEY

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ABSTRACT

In the plasma flow round Comet Halley two unexpected structural features were observed in addition to the anticipated bow shock and contact discontinuity. These features, observed between the structure identified as bow shock and the contact discontinuity are described.

INTRODUCTION

The JPA instrument on Giotto carried two three-dimensional positive-ion analysers /1/. The Fast Ion Sensor obtained an energy/charge distribution once per spin, without mass discrimination; the Implanted Ion Sensor included time-of-flight analysis for mass discrimination but required 32 spins to obtain a complete energy distribution up to 90 keV. The two sensors observed the interaction between the solar wind and the implanted cometary ions as the Giotto spacecraft traversed the coma of Halley's Comet travelling at 73° to the comet-sun line and passing 600 km sunward of the nucleus.

OBSERVATIONS

The measurement made by the Implanted Ion Sensor is shown in figure 1. The panels show data from three of the five detectors within the sensor set at different polar angles with respect to the spacecraft velocity vector and spin axis. The sensor classifies each event into one of five mass groups on-board. The data in these panels are for the mass group between 13 and 25 amu. However, because the fluxes in the solar wind are very high, there is a pile-up effect in the time channel which leads to some solar wind ions appearing in the heavier mass groups. Since the energy spectra of the solar wind protons and the heavy cometary ions are quite distinct, we can take advantage of the effect to show both populations in a single plot, although the relative number of counts between the two populations is not correct. The lower energy spectrum is the solar wind; the upper energy spectrum is cometary ions in the water group. Overall, the plot shows the solar wind being slowed down more and more by the addition of cometary ions to the flow. The energy and direction of the cometary ion flow indicates that they are being injected nearly

perpendicular to the magnetic field, without significant pitch angle scattering outside the bow shock /2/.

The bow shock is one of two structural features that had been expected to exist in the plasma flow around a comet. The other was the contact discontinuity. Both these features were found by Giotto. The bow shock is a complex structure found between 1.13×10^6 kms and 1.00×10^6 kms on the inbound leg with a foreshock region extending 250,000 kms outside the bow shock. These features have been described in more detail elsewhere /3/. The contact discontinuity was detected by both the magnetometer /4/ and the ion mass spectrometer /5/ on Giotto at a distance of 4700 kms from the nucleus. We concentrate the discussion here on two other structural features which had not been anticipated. The first occurs inbound at 2200 GRT when the spacecraft was 0.53×10^6 kms from the nucleus. Between the bow shock and this point the energy spectrum of the watergroup cometary ions is relatively broad extending from less than 20 keV up to more than 60 keV. At 2200 the spectrum changes suddenly (within 5 minutes) and develops a double peak. The high energy portion continues at the energy of the peak of the previous spectrum but at a reduced intensity. The second peak appears near the lower energy limit of the previous spectrum. After the sudden transition the high energy peak remains near the same energy but continues to decrease in intensity; the low energy peak increases in intensity but decreases in energy. A possible explanation is that the new low energy peak is formed from newly-ionized cometary particles created by charge-exchange with the more energetic ions created at greater distances. The lower energy of the new ions is the result of the draping of magnetic field lines around the nucleus, which decreases the angle between the flow and the field /2/. While this explanation seems consistent with the data it is not clear why the transition from the previous regime occurs so suddenly. A similar transition occurs on the outbound leg at a distance of 0.47×10^6 kms /6/.

The second unexpected structural feature occurs at 2338 GRT and is shown in detail, using Fast Ion Sensor data, in figure 2. The lower panel which covers the angular range $20^\circ - 72^\circ$, closest to the spacecraft velocity vector and spin axis, shows both components in the energy spectrum; the upper panel, containing data from larger angles, $72^\circ - 124^\circ$, shows only the lower-energy, solar wind component. At 2338 GRT, 135,000 kms from the nucleus the solar wind component decreases rapidly in intensity and disappears from both panels simultaneously. The high energy, cometary-ion component penetrates to a distance of 61,200 kms from the nucleus, finally disappearing at 2356 GRT. The disappearance of the solar wind coincides with the beginning of the magnetic-field pile-up /4/.

On the outbound leg the structure is similar but not identical. Both solar wind and cometary components penetrate to a distance of 65,000 kms (0027 GRT) although there is another sharp increase in the solar wind flux at 0057 GRT, 188,000 kms from the nucleus. On the outbound leg there is no clear correlation with the magnetic field strength which decreases more steadily /4/ away from the nucleus.

This feature, namely the disappearance of solar wind ions, has been reported by Gringauz et al /7/ using data from the VEGA-2 spacecraft at a distance of 160,000 km from the nucleus on the inbound leg. Simultaneously they observe an increase in flux of cold cometary ions in the ram direction. No information is available from the JPA instrument on this component since the ram direction was covered by other instruments on Giotto. Unlike Giotto there is no significant correlated change in the magnetic field during the Vega 2 encounter /8/. Gringauz et al /7/ have called this feature the cometopause and have pointed out that it is a boundary between regions of different chemical composition.

SUMMARY

In addition to the two expected features, a bow shock, and a contact discontinuity, two other sharp transitions have been found in the plasma flow around comet Halley. They are:

a) a transition from turbulent plasma containing accelerated cometary ions, to a less disturbed region containing two distinct populations of cometary ions at 540,000 km from the nucleus.

b) the disappearance of flowing plasma of solar wind origin at 135,000 kms from the nucleus.

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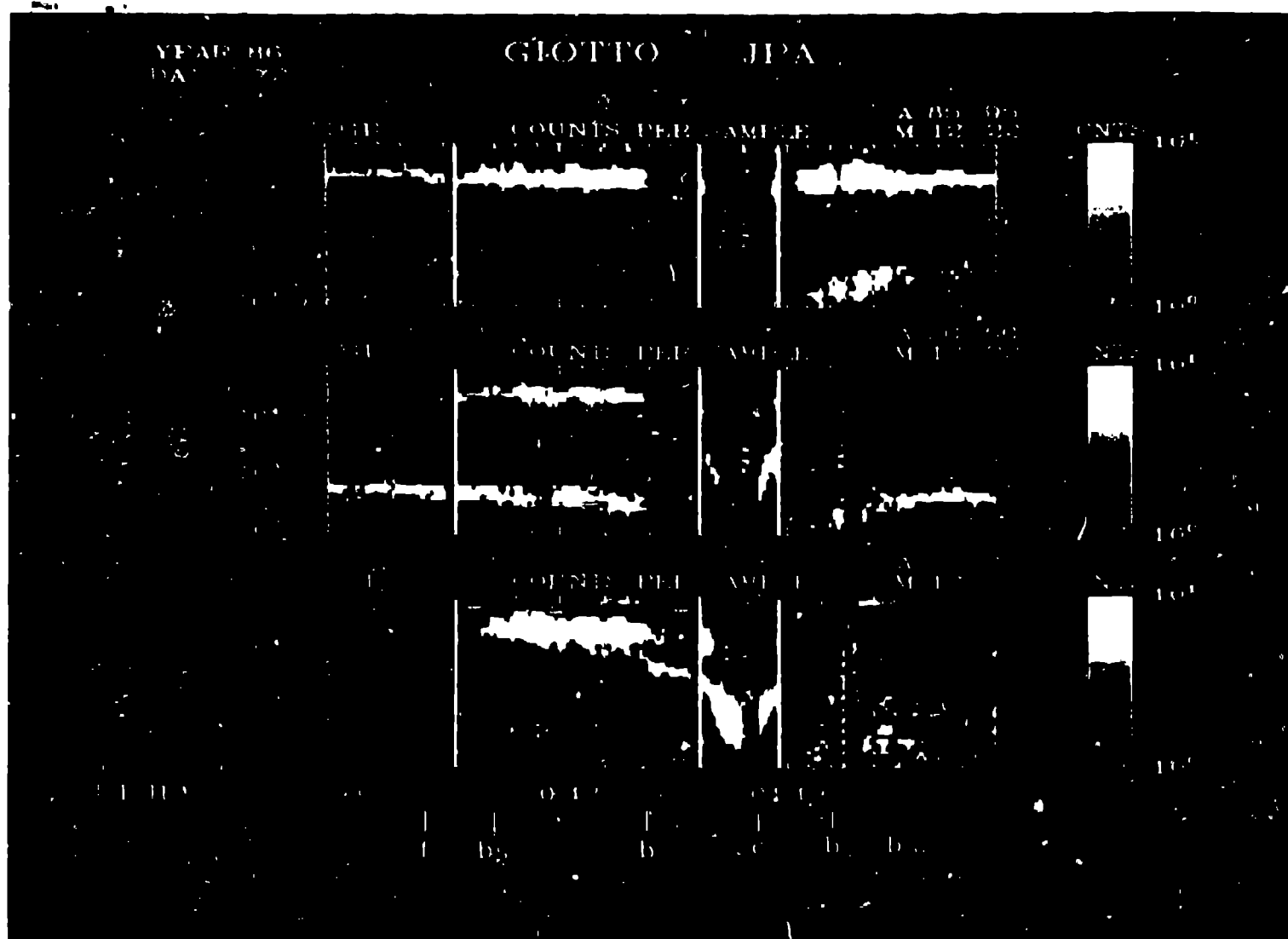


Fig. 1. An overview of the plasma flow at Comet halley. The three panels show energy/time spectrograms with the intensity given by the grey scale shown by the side. The position of the various structural features (see text) are marked by letters as follows: f - foreshock, bs - bow shock, b - bifurcation, c - closest approach. At closest approach, this sensor became switched to the wrong status by on-board noise and could not be restored for 30 minutes. This data gap is not plotted. After closest approach the sensor plotted in the bottom panel became noisy.

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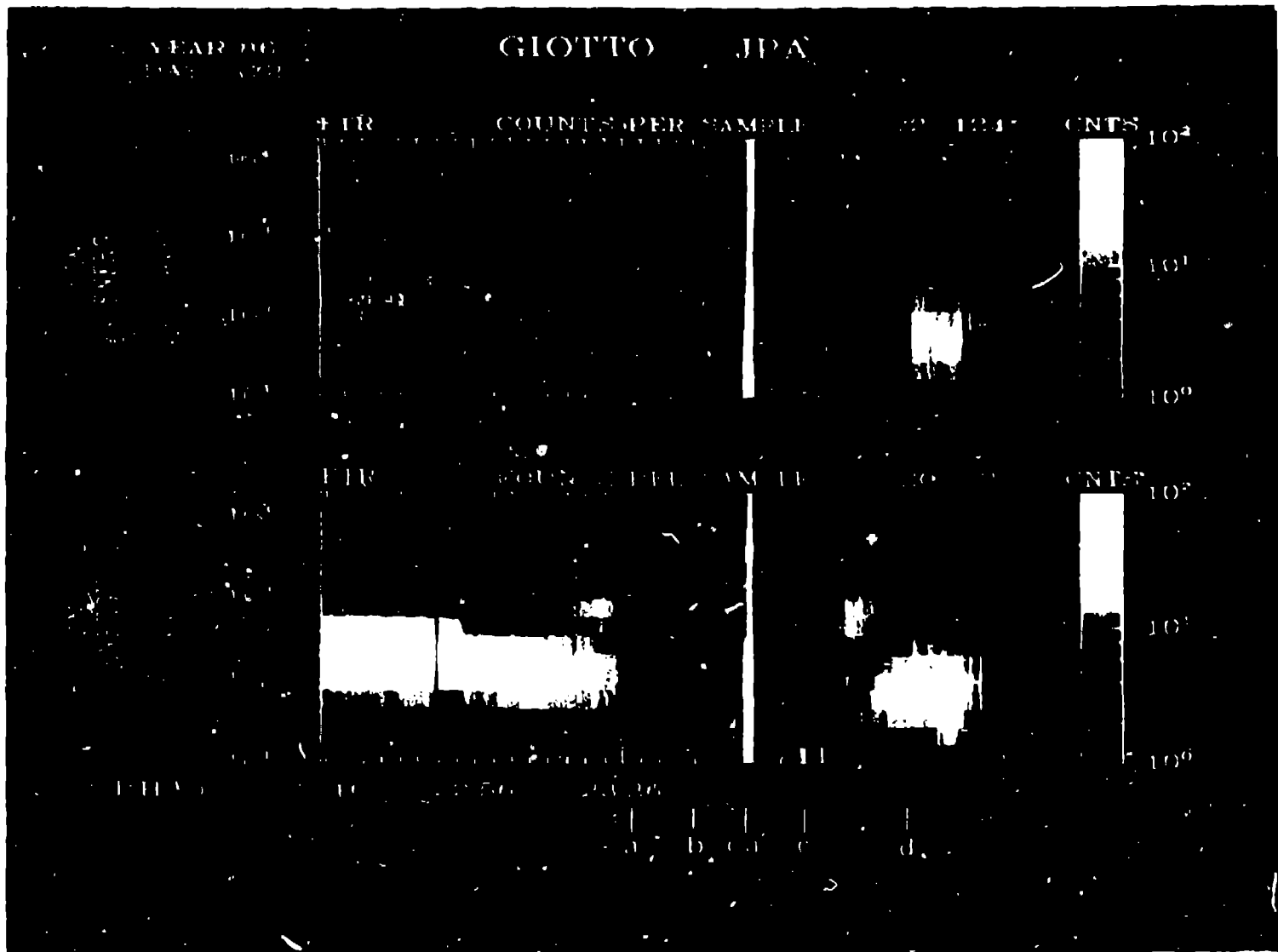


Fig. 2. A plot of the measurements taken within approximately 4×10^5 kms of the nucleus. The four times referred to in the text are marked; a - 2238, b - 2256, c - 0027, d - 0057, all times are UT when the signal was received at the ground. ca - marks the position of closest approach where high intensities of dust impact plasma were recorded.